Patterns of Informal Reasoning in the Context of Socioscientific Decision Making

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Abstract: The purpose of this study is to contribute to a theoretical knowledge base through research by examining factors salient to science education reform and practice in the context of socioscientific issues. The study explores how individuals negotiate and resolve genetic engineering dilemmas. A qualitative approach was used to examine patterns of informal reasoning and the role of morality in these processes. Thirty college students participated individually in two semistructured interviews designed to explore their informal reasoning in response to six genetic engineering scenarios. Students demonstrated evidence of rationalistic, emotive, and intuitive forms of informal reasoning. Rationalistic informal reasoning described reason-based considerations; emotive informal reasoning described care-based considerations; and intuitive reasoning described considerations based on immediate reactions to the context of a scenario. Participants frequently relied on combinations of these reasoning patterns as they worked to resolve individual socioscientific scenarios. Most of the participants appreciated at least some of the moral implications of their decisions, and these considerations were typically interwoven within an overall pattern of informal reasoning. These results highlight the need to ensure that science classrooms are environments in which intuition and emotion in addition to reason are valued. Implications and recommendations for future research are discussed. © 2004 Wiley Periodicals, Inc. J Res Sci Teach 42: 112–138, 2005

The phrase ‘‘socioscientific issues’’ has come to represent a variety of social dilemmas with conceptual, procedural, or technological associations with science (Fleming, 1986; Kolstø, 2001; Patronis, Potari, & Spiliotopoulou, 1999; Zeidler, Walker, Ackett, & Simmons, 2002). Socioscientific issues typically involve the products or the processes of science and create social debate or controversy. Current socioscientific issues frequently stem from biotechnological advances such as cloning, stem cells, and genetically modified foods and environmental challenges such as global climate change, land-use decisions, and the introduction of exotic substances (both biotic and abiotic). The delineation of socioscientific issues should not imply that

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those issues not classified as such cannot be mutually influenced by science and society. We fully recognize that the domain commonly designated ''science'' is a human product and, therefore, is necessarily bound to the society from which it arises (Abd-El-Khalick, Bell, & Lederman, 1998; McComas, Clough, & Almazroa, 2000). However, using the phrase ''socioscientific issues'' enables researchers and practitioners alike to economically discuss a group of issues that share distinct features (i.e., based on science concepts or problems, controversial in nature, discussed in public outlets, and frequently subject to political and ethical influences).

Recent conceptualizations of socioscientific curriculum distinguish it from previous approaches such as the science–technology–society (STS) movement. Whereas STS tends to focus on the impact of science and technology on society, it typically does not explore the moral and ethical implications that underlie these issues. In contrast, the socioscientific issue movement arises from a conceptual framework that unifies the development of moral and epistemological orientations of students and considers the role of emotions and character as key components of science education (Sadler, 2004a; Zeidler & Keefer, 2003; Zeidler, Sadler, Simmons, & Howes, in press).

Socioscientific issues have become important in science education because they occupy a central role in the promotion of scientific literacy (Bingle & Gaskell, 1994; Driver, Leach, Millar, & Scott, 1996; Zeidler & Keefer, 2003). This perspective on scientific literacy, which is consistent with standards and reform documents in the United States (American Association for the Advancement of Science, 1990; National Research Council, 1996; Siebert & McIntosh, 2001) and abroad (Council of Ministers of Education Canada Pan-Canadian Science Project, 1997; Millar & Osborne, 1998; Queensland School Curriculum Council, 2001), holds that science students require the ability to make informed decisions regarding scientific issues of particular social import. Scientific literacy, at least in part entails the ability to discuss, interpret relevant evidence, and draw conclusions in response to socioscientific issues. Because the promotion of scientific literacy, as envisioned in the aforementioned documents, defines a (if not the) fundamental goal of science education and socioscientific decision making represents an integral component of this goal, we believe it necessary to explore how students negotiate and resolve socioscientific issues. Explicating the processes and patterns students use as they confront controversial dilemmas in science will aid the development of appropriate socioscientific curricula and pedagogical strategies, thereby enhancing the promotion of scientific literacy. In doing so, we aim to contribute to building a theoretical knowledge base through research by examining factors salient to science education reform and practice in the context of socioscientific issues. This will entail reviewing relevant literature related to informal reasoning regarding socioscientific issues and presenting an empirical investigation that addresses questions derived from this previous work.

Theoretical Context

Socioscientific issues differ from other issues in science in that they are open-ended, ill-structured, debatable problems subject to multiple perspectives and solutions. The negotiation and resolution of such complex problems can be characterized generally by the process of informal reasoning. Individuals engage in informal reasoning as they attempt to work out contentious problems without clear-cut solutions (Kuhn, 1991; Means & Voss, 1996; Perkins, Farady, & Bushey, 1991). Informal reasoning as a construct subsumes the cognitive and affective processes that contribute to the resolution of complex issues. In an article discussing student thinking regarding human genetics dilemmas, Zohar and Nemet (2002) described the concept:

> It [informal reasoning] involves reasoning about causes and consequences and about advantages and disadvantages, or pros and cons, of particular propositions or decision

> alternatives. It underlies attitudes and opinions, involves ill-structured problems that have no definite solution, and often involves inductive (rather than deductive) reasoning problems. (p. 38)

Outside the field of science education, others have attempted to provide a developmental model of informal reasoning. In a review of longitudinal studies, King and Kitchener (2004) explored how the reflective judgment model (RJM) reveals differing epistemic assumptions in the way individuals create and justify their own reasoning about ill-structured problems. Their model involves a six-stage developmentally sequenced model that entails prereflective, quasireflective, and reflective thinking and is modeled after the probabilistic notion (Rest, Narvaez, Bebeau, & Thoma, 1999) of stage development (one does not have to be ‘‘in a stage’’ but may exhibit varying degrees of overlapping stage sophistication depending on the context of the situation, familiarity with the problem, and personal motivation to engage in reasoning about that problem). Although the controversial problems investigated entail a high degree incompleteness and cannot be resolved with a high degree of certainty, they tend to be focused on more generalized social issues. Likewise, socioscientific issues are open-ended, ill-structured, debatable problems, and we use the term informal reasoning to describe how individuals negotiate and resolve them. Our research focuses on problems that have explicit and implicit connections to science and implications for the practice of science education. We conducted this investigation with the intent of exploring patterns of informal reasoning in the context of socioscientific issues.

Several empirical reports have addressed aspects of informal reasoning in the context of socioscientific issues. Sadler (2004b) reviewed many of these studies, focusing specifically on the following themes: the expression of informal reasoning through argumentation; relationships between nature of science (NOS) conceptualizations and socioscientific informal reasoning; patterns of data interpretation and information evaluation; and the influence of conceptual understanding of material related to a socioscientific issue and informal reasoning. Many of these findings, in addition to a few reports not included in that review, are particularly relevant in framing the current study. Other studies related to science education focus on the promising use of technology as a means of engaging students in arguments via knowledge integration environments (Bell & Linn, 2000), using web-based inquiry science environments (WISE) aimed at presenting conflicting views of scientific phenomena to students (Linn, Clark, & Slotta, 2003; Linn, Shear, Bell, & Slotta, 1999), and using computer feedback programs such as Convince Me, which allows students to develop metacognitive skills by creating representations of their own reasoning patterns and to reflect on the efficacy of those patterns (Adams, 2002). Our work differs in that our attention is focused on more explicit forms of informal reasoning patterns in the context of socioscientific issues, and the corresponding moral and ethical issues perceived by students.

This investigation assumes the challenge of exploring, describing, and explaining how students think and feel about a series of related socioscientific issues (viz., genetic engineering dilemmas); therefore, in building a theoretical framework for the study, we focus most intently on those reports that begin to describe patterns of student thought in the context of socioscientific issues (Bell & Lederman, 2003; Fleming, 1986; Hogan, 2002; Kortland, 1996; Patronis et al., 1999; Pedretti, 1999; Sadler, Chambers, & Zeidler, 2004; Sadler & Zeidler, 2004; Yang & Anderson, 2003; Zeidler & Schafer, 1984; Zeidler et al., 2002). Analysis of these findings reveals several trends pertinent to the current study including the significant influence of personal experiences, emotive considerations, a tendency to focus on social considerations, the primacy of morality in many socioscientific contexts, and variability in students’ perceptions of the complexity inherent to these issues.

Personal Experiences

In a qualitative analysis of college student reasoning patterns regarding a set of environmental issues, Zeidler and Schafer (1984) revealed that decisionmakers frequently rely on personal experiences as guides for the resolution of socioscientific dilemmas. The participants tended to relate hypothetical scenarios, provided by the researchers for participant consideration, to their own experiences. Relating dilemmas to their own experiences served as a means of access to the issue as well as a means of framing their argument. In other words, participants initially used their experiences to help interpret dilemmas and, as the students began to discuss their opinions about the dilemmas, personal experiences served as rationales for the positions articulated. The significance of personal experiences in the context of socioscientific decision making has been supported in a variety of studies employing different issues and samples. Fleming (1986) found the personal domain to be an important influence on high school student reasoning regarding both genetic engineering and nuclear power. Sadler and Zeidler (2004) also used human genetic engineering scenarios but worked with college students and reported similar results. Patronis et al. (1999) and Sadler et al. (2004a) both noted the central role played by personal experiences in high school student reasoning in response to distinct environmental challenges. Finally, Zeidler et al. (2002) noted similar patterns with both high school students and preservice teachers as they wrestled with issues related to animal rights and experimentation.

Emotive Considerations

On a conceptual level, emotive consideration may be distinguished from other factors (personal, cognitive, social, etc.), but in practice it may be an academic point because of the pervasive influence emotions have on how students frame and respond to ethical issues. Although educators have long been aware of the importance of the affective domain in engaging students, the roles of empathy, caring, or sympathy are of particular interest in the exploration of socioscientific issues (SSI). Both empathy and sympathy have been used interchangeably in the social science literature (Eisenberg et al., 1994) and entail an emotional reaction that includes feelings of concern for other individuals' needs. Although a conceptual analysis of both terms may provide subtle, fine-grained distinctions between empathy and sympathy, it is unimportant for our purposes where the essential quality is the capacity for students to evoke a degree of perspective-taking for the purposes of engaging in a sustained line of reasoning about the (ethical) problem at hand. Research has demonstrated that higher levels of emotional (affective) engagement, coupled with the ability to regulate and control that emotional engagement through communicative and social mechanisms, leads to increased resilience, empathetic responses, prosocial behavior, and constructive coping behaviors (Eisenberg, 2000; Eisenberg et al., 1994; Eisenberg & Fabes, 1992). The role of emotions has recently been examined in the context of SSI in science education (Sadler & Zeidler, 2004) and has been found to have a facilitative effect in terms of students' engagement with controversial issues. In this research, half of the sample indicated that emotions contributed significantly to their consideration and resolution of the SSI under investigation. It is within this context that sympathy/empathy has allowed the students to identify with the characters in the SSI scenarios and allow for multiple perspective-taking.

Social Considerations

Fleming (1986) framed the analysis of socioscientific decision making using a domain account of knowledge (Turiel, 1983). He concluded that knowledge of the social world, as opposed to the physical world, was the most important determinant of student reasoning: ‘‘Adolescents define socio-scientific issues in a way which stresses the social aspects of the issue’’ (Fleming, 1986, p. 680). Yang and Anderson (2003) quantified the extent to which high school students possess social and scientific orientations toward the issue of nuclear energy by analyzing the types of information students preferred as well as reasoning patterns employed throughout interviews. Whereas Fleming (1986) concluded that social knowledge was more instrumental in socioscientific decision making, Yang and Anderson (2003) suggested a more variable pattern. Individuals varied in the extent to which they held scientific or social orientations. The authors suggested a somewhat normal distribution of reasoning orientations: the majority of individuals in the study maintained some combination of social and scientific orientations, whereas fewer individuals held strictly social or scientific orientations. This result was consistent with Sadler et al. (2004), who noted that students were concerned with the evidence and data associated with different positions as well as the social consequences of the positions. Both Zeidler et al. (2002) and Sadler and Zeidler (2004) supported this general trend of social import for informal reasoning and highlighted the role of a particular social institution, religion. Participants in both of these studies frequently cited their own religious ideas or those of their families as important factors contributing to their decision making. It is of interest to note that these individuals did not necessarily equate such religion-based ideas as moral imperatives but rather social guidelines.

Morality

Some investigators (e.g., Andrew & Robottom, 2001; Evans, 2002; Zeidler & Keefer, 2003) have contended that socioscientific issues, by definition, involve morality, and several studies have supported this claim empirically. Fleming (1986) concluded that 70% of the adolescents he interviewed employed morality in the resolution of genetic engineering and nuclear energy. In a study involving older participants, academics from a variety of disciplines, Bell and Lederman (2003) concluded that 85% of their participants’ responses to a series of issues related to biotechnology and human health involved moral, ethical, or value considerations. Pedretti’s (1999) work with fifth and sixth graders revealed that students actively contrasted the notion of rights versus societal laws, made utilitarian calculations of effects, and applied principles of justice when confronted with a local environmental dilemma. Both Zeidler and Schafer (1984) and Hogan (2002) found support for the contention that participants of varying ages, middle school (Hogan, 2002) and college aged (Zeidler & Schafer, 1984), actively employ moral reasoning as they work through environmental issues. Unlike many of these studies that addressed socio-scientific issues more generally, Sadler and Zeidler (2004) specifically sought to explore the moral aspects of decision making in the context of genetic engineering issues. The college students participating in this study displayed consequentialist (decisions based on an assessment of the consequences of SSI) and principle-based moral reasoning (decisions based on the application of moral principles or prescripts). In addition, they also demonstrated a tendency to rely on moral emotions and moral intuition as they sought resolution of the socioscientific scenarios.

Perceptions of Complexity

A final trend to emerge from these studies of socioscientific informal reasoning was the extent to which decisionmakers perceived the inherent complexity of the issues they sought to resolve. Whereas the participants in some of the studies demonstrated a tendency to recognize that socioscientific scenarios lack clear-cut solutions because of conflicting interests and multiple interpretations, other studies suggested that decisionmakers failed to perceive issue complexity.

Pedretti (1999) was impressed with the extent to which her middle school participants appreciated the complexity of a local environmental issue. The students recognized many viewpoints and actively reflected on the multifarious implications of their decisions, the importance of reliable information, individual biases, and the need to compromise. Yang and Anderson (2003) also noted that at least some of the high school students participating in their investigation displayed considerably integrated patterns of reasoning. However, this trend was not reflected in other reports. Hogan (2002) reported that eighth grade students did not recognize the multifaceted nature of an environmental issue as they discussed the dilemma in individual interviews or in small group interactions. Students focused narrowly on one aspect of the problem without appreciating diverse perspectives and repercussions. Kortland (1996) found complementary results with similarly aged participants. Even after a classroom instructional program aimed at improving decision making with respect to evaluating alternative concerns, students remained relatively limited with respect to their perceptions of complexity. A comprehensive analysis of the results from all four of these studies remains difficult because of a lack of regularity with which the authors assessed participant perceptions of complexity. One explanation for the apparent inconsistencies is variability among the individuals comprising each sample. Alternatively, the scenarios to which the individuals responded could have been sufficiently variable to account for the disparate results. Another possibility is the uniqueness in approach of each of the investigators and their interpretations of how effectively participants appreciated the complexity of issues. Finally, Felton and Kuhn (2001) suggested that normative models of social discourse recognize that strategic performance (e.g., the ability to raise transactive statements, form counter positions, seek evidence, etc.) is dependent on developmental levels of students. Although this departs from earlier work that suggested argumentative reasoning did not vary much from adolescence through older age (Kuhn, 1992), it does coincide with the findings of Zeidler, Osborne, Erduran, Simon, and Monk (2003) in that the developmental status of older students certainly favors more sophisticated arguments, but does not make them immune from the pitfalls of fallacious argumentation patterns.

Focus of the Research

In this study, we extend the investigation of informal reasoning regarding socioscientific issues. Previous work in this area has suggested several tendencies among decision makers: reliance on personal experiences; the influence of emotive factors; the primacy of social considerations; and moral and ethical calculations. The purpose of this study is to explore the extent to which individuals integrate these tendencies into overall patterns of informal reasoning. We seek to provide an empirical basis for the construction of a model of socioscientific informal reasoning by characterizing patterns of student reasoning as they negotiate and resolve a series of scenarios related to genetic engineering. Given the consistency with which earlier reports have attested to the importance of morality and ethics in socioscientific contexts (Bell & Lederman, 2003; Fleming, 1986; Hogan, 2002; Pedretti, 1999; Sadler & Zeidler, 2004; Zeidler & Schafer, 1984) and the potential significance this result has for individual decision making (Sadler & Zeidler, 2004), we paid particular attention to how moral considerations are coordinated and evoked in overall patterns of informal reasoning.

Methods

Based on the aims of our investigation, namely the explication of student informal reasoning with a focus on the moral aspects of decision making, we employed qualitative methods. This approach enabled us to explore an extremely open-ended problem that allows for rich and protracted narrative discourse in a manner that cannot be accessed with quantitative instruments. Qualitative methods also freed us from the constraints imposed by narrow a priori hypotheses, thereby permitting a more robust inductive analysis of the data. We conducted semistructured interviews with 30 college students on the topic of human genetic engineering. Each student participated individually in two separate interviews with the first author.

Sample

Previous work has identified the need to investigate socioscientific informal reasoning with participants of various ages (Sadler, 2004b; Yang & Anderson, 2003). In this study we chose to work with college students. We recruited 15 participants with extensive experience in natural science courses from upper division biology courses. Another 15 students, recruited from upper division psychology classes, who had limited experiences with natural science coursework, rounded out the sample. All students were enrolled at a large public university in the southeastern United States. This work was part of a larger study with the additional aim of exploring the significance of content knowledge in informal reasoning regarding SSI (Sadler & Zeidler, in press). This research goal accounts for why we chose to work with a targeted sample of junior- and senior-level students, half of whom possessed extensive knowledge of genetics and the other half of whom who revealed relatively limited understanding of genetics.

Some moral psychology researchers (Ford & Lowery, 1986; Gilligan, 1982) have noted divergent patterns of moral reasoning in the different genders. Although this study proceeded under the assumption that males and females do not engage in inherently different forms of moral decision making (Friedman, Robinson, & Friedman, 1987; Hekman, 1995; Singer, 1999; Tronto, 1987), we constructed the sample so that both male and female voices were represented relatively equally. Sixteen females (8 science majors and 8 nonscience majors) and 14 males (7 science majors and 7 nonscience majors) comprised the sample.

Issue Selection and Interview Protocol

In selecting an issue to serve as the focus of our interviews, we sought a common theme with the potential to develop multiple scenarios. This strategy afforded participants opportunities to make several decisions without completely disrupting conversational flow by introducing unrelated topics. We selected genetic engineering, in part, because of the facility with which we could develop numerous dilemmas involving gene therapy and cloning, and because this topic has engaged students in protracted narrative discourse in prior studies (Sadler & Zeidler, 2004; Walker, 2003). We asked students to consider the use of gene therapy for eliminating Huntington's disease, correcting near-sightedness, and enhancing intelligence. Students also discussed their ideas about reproductive cloning as an infertility treatment and a means of replacing a deceased child as well as therapeutic cloning for the purpose of organ production. Another factor contributing to the selection of socioscientific topics was the likelihood that target participants would construe the issues as moral problems. Because we wanted to investigate how morality is incorporated in overall patterns of informal reasoning, we sought issues that college students tended to perceive as moral problems. Previous work has shown that gene therapy and human cloning meet this requirement (Sadler & Zeidler, 2004).

The initial interviews consisted of questions related to the six different genetic engineering scenarios just described. Participants began the interview by reading a brief description of gene therapy and then a prompt describing a specific gene therapy scenario (see Appendix A for the descriptions and reading prompts). The first author asked whether or not the participant approved of gene therapy in this context. The interviewer then posed questions designed to elicit a rationale to support the position just advanced. Following the articulation of a rationale, the participant was asked to describe and explain a possible counterposition. The counterposition was an argument that opposed the original position offered by the participant. Finally, the participant was asked to offer a rebuttal to refute the counterposition, thereby supporting his/her position. The participants repeated these procedures, reading about a specific scenario related to gene therapy and answering interview questions, two additional times. The same pattern was repeated for the three cloning scenarios. Participants read an initial description of cloning followed by three specific cases that required a decision regarding the appropriateness of cloning in context. After the participants read each scenario prompt, the interviewer posed questions to elicit positions, rationales, counter-positions, and rebuttals (see Appendix B for an elaboration of interview questions from the first interview). This protocol was modeled after Kuhn's (1991) investigation of informal reasoning and argumentation. Because of our interest in patterns of informal reasoning and not necessarily the quality of argumentation, we provided prompts and probes, in the form of explicitly asking for positions, rationales, counterpositions, and rebuttals, to encourage the expression of reasoning.

During the second interview, the first author reviewed two scenarios (one based on gene therapy for Huntington's disease and the other based on reproductive cloning) as well as positions and rationales originally offered by the participant in the first interview. The participant was given a chance to reflect on his/her position, as interpreted by the researcher, and clear up any misinterpretations. The interviewer then posed a series of questions aimed at uncovering details regarding the influence of personal experiences, social considerations, and moral construal on overall informal reasoning patterns. For example, one scenario to which the participants reacted involved gene therapy for Huntington's disease. The participant had already stated a position regarding whether or not they thought gene therapy should be used in this particular context (during the first interview). The interviewer asked the participant whether he or she had considered a series of factors, such as the feelings of individuals involved, applicable moral principles or perspectives, rights and responsibilities, and his/her own immediate reactions in the determination of that position (see Appendix C for a complete list of second interview questions).

Although we used pre-set protocols for both sets of interviews, we conducted the meetings in a semistructured manner so as to encourage protracted discourse. The first author conducted all of the single-participant interviews in a private office, and the dialogs were audio-recorded. The tapes were transcribed in their entirety producing 362 pages of transcripts. We base our analyses on these interview transcripts.

Analysis

Participants' ideas and arguments were explored in a manner consistent with inductive data analysis as described by Lincoln and Guba (1985), and the constant comparative method described by Glaser and Strauss (1967). To carry out this analysis, the first author read through both sets of transcripts in several iterations making preliminary notes regarding patterns that emerged from individual participants. The emergent categories were then used to classify the arguments offered by each participant in response to all of the scenarios presented. The first author repeated this last step, blind to the previous assessments. Any discourse patterns that were classified differently in the second and third round of reviews were carefully considered and reconciled. The second author examined six randomly selected sets of transcripts (the first and second interviews from six individuals) to confirm the appropriateness of the emergent taxonomy originally developed by the first author. The second author also checked the original placement of argument patterns in specific categories of the emergent taxonomy. The rate of corroboration between the two authors in categorizing participant reasoning for each of the six scenarios exceeded 95%. Given this high rate of interrater agreement on the randomly selected transcripts, we were satisfied with the legitimacy of the taxonomic analysis.

We specifically aimed to extract meaning reflective of the participants' reasoning patterns and, therefore, selected propositions as the unit of analysis. In many cases, participants strung together several propositions indicative of a particular pattern of reasoning (individual reasoning patterns are described more in depth in the Results section). In other instances, adjacent propositions provided evidence of unique reasoning patterns. All analyses were coded manually, and we did not make use of specific text markers. Instead, we relied on our own abilities as "research instruments" to recognize emergent patterns of meaning from the propositions offered.

Trustworthiness

We used a number of techniques to bolster the trustworthiness (Lincoln & Guba, 1985) of our work. To build credibility and confirmability (generally analogous to validity in quantitative paradigms), we employed "investigator triangulation" to guard against the misinterpretation of data. As mentioned in the Analysis section, both authors independently reviewed 20% of both sets of interview transcripts to build consensus regarding the emergent analysis. Member checking was also used to enhance trustworthiness. Although we, as the investigators, assumed the responsibility of interpreting the data, the participants themselves actually provided the data and therefore, possessed the unique ability to identify whether the researcher's interpretations were in fact credible. During the second round of interviews, participants had an opportunity to reflect on the investigators' interpretation of their reasoning presented in the initial interview. Through this experience, participants were able to correct, clarify, or confirm the investigator's interpretation of their informal reasoning patterns. Finally, an audit trail was maintained to further enhance confirmability. The audit process for qualitative research is a comprehensive approach to record-keeping throughout the course of the investigation. The audit trail included detailed notes regarding data collection and analysis with particular attention to any modifications made. The audit trail also involved organization of the raw data (viz., audio-tapes and transcripts), data reduction, analysis strategies, analytical products, and protocol development information (Lincoln & Guba, 1985).

Results

Given the qualitative nature of this study's findings, the presentation of data is necessarily embedded in a description of the findings. This section presents results and analyses of the context and meaning of these results. All the quotations offered in support of our interpretations are preceded by an alpha-numeric code, which identifies the quoted participant, the interview, and the scenario to which he or she is responding. The first number, which can range from 1 to 30, identifies a specific participant. This number is followed by either an "F" or an "S"; the "F" indicates that the quotation was taken from the first interview, and the "S" indicates that the quotation was taken from the second interview. The last two letters of the code are offset parenthetically and represent one of the six scenarios. "HD" represents the Huntington's disease gene therapy scenario; "NS" represents the near-sightedness gene therapy scenario; "IN" represents the intelligence gene therapy scenario; "RC" represents the reproductive cloning scenario; "DC" represents the deceased child cloning scenario; and "TC" represents the therapeutic cloning scenario. "Int" represents the comment or question of the interviewer.

The informal reasoning displayed by participants in response to the genetic engineering scenarios incorporated both cognition and affect. In many cases, participants used reason in a deliberate manner to negotiate and resolve particular issues. They also frequently relied on their feelings and emotions to work out dilemmas. As mentioned previously, we employ the phrase "informal reasoning" to characterize general processes of negotiating and resolving socio-scientific issues. Therefore, this terminology subsumes both cognitive and affective processes.

In some instances of cognitive informal reasoning, participants relied solely on reason and logic to formulate and support their positions. Although individuals reasoned about many different considerations including, but not limited to, patient rights, side effects, issues of access, technological concerns, and the severity of disease conditions, all of these patterns of thought were grouped under the heading of *rationalistic* informal reasoning. In some cases of affective informal reasoning, participants resolved scenarios based on their immediate feelings or reactions. Individuals displaying this type of thought pattern had an immediate positive or negative reaction to the scenario, and these feelings contributed to their negotiation and eventual resolution of the issue. This pattern was termed *intuitive* informal reasoning. Finally, some participants displayed patterns consistent with both cognition and affect. This pattern of informal reasoning involved emotions typically classified as moral emotions, namely empathy and sympathy (Eisenberg, 2000). In these cases, participants displayed a sense of care toward the individuals who might be affected by the decisions made. These participants were empathetic toward the well-being of others. This classification, which was rational and rooted in emotion, was termed *emotive* informal reasoning. Emotive reasoning differed from rationalistic reasoning in that rationalistic reasoning lacked the influence of emotions. Emotive and intuitive informal reasoning were both affective classifications but remained unique, because, whereas emotive patterns were directed toward real people or fictitious characters, intuitive patterns were personal reactions in response to specific aspects of the scenario.

The emergent framework of informal reasoning can be visually conceptualized in the form of a Venn diagram (Figure 1). Each circle represents one of the informal reasoning patterns (i.e.,

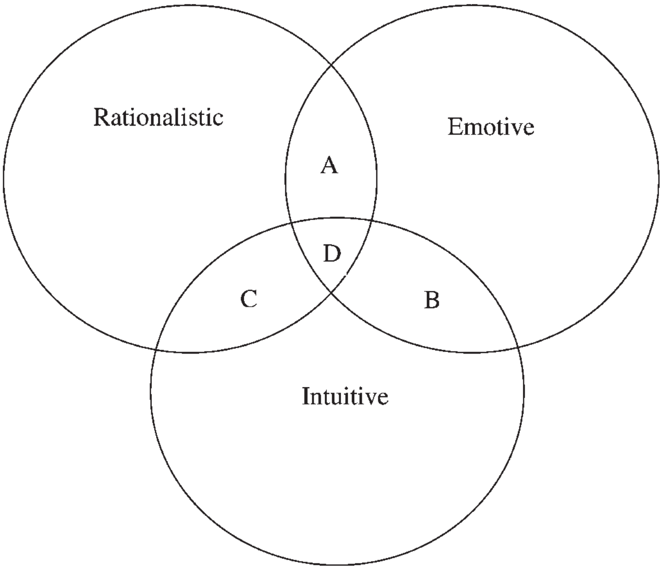

Figure 1. Graphic display of the emergent patterns of integrated informal reasoning regarding socioscientific issues.

rationalistic, emotive, and intuitive). It should be noted that participants showed evidence of integrating multiple informal reasoning patterns in response to single scenarios. The areas of overlap in Figure 1, labeled A–D, represent the potential to engage in multiple patterns of informal reasoning. In the remainder of this section, each of these reasoning patterns and combinations will be described and substantiated with data from the interviews.

Rationalistic Informal Reasoning

All participants used rationalistic thought processes to guide their decision making in at least some of the genetic engineering scenarios presented to them. They made rationalistic calculations based on a variety of factors, such as patient rights, parental responsibilities, availability of other treatment options, side effects, future applications, and discrepancies in terms of access. The quotes below provide samples of how students relied on rationalistic informal reasoning:

- 1F(IN): The other ones [the Huntington's disease and nearsightedness scenarios] are diseases. This [intelligence] is something that you are born with. It is who you are; it is your personality; it has more factors that go into it. Those are ailments or deficiencies—this is not a deficiency. It may be a deficiency to some extent if a person has an extra chromosome or whatever that makes them retarded, but to make them smarter, no. I do not think so.
- 18F(TC): Right now, there is a black market for organs so if you could create an organ, then that would be justifiable. The ends justify the means kind of thing . . . You have to weigh all the options and decide whether it is worth the risk.
- 23F(HD): That is kind of a tricky question because there are a lot of issues with that. I think when you do that, when you use gene therapy to fix these problems, it is kind of artificial natural selection because naturally you would breed those genes out, I guess. I guess in the case of Huntington's disease, it comes on later so they have already reproduced. But if you can get rid of a disease that seems like, why not? The only problem that I see with genetic engineering is there is going to be a cost thing. Are only some people going to be able to afford it? . . . There might be a class difference.

The interview excerpts just presented do not capture every reason-based consideration articulated in the interviews, but they do provide evidence to support the notion that rationalistic thought processes contributed to the resolution of socioscientific issues. In thinking about gene therapy for intelligence, participant 1 made a rationalistic distinction between deficiencies and other types of inherited traits. Participant 18 employed ends-and-means reasoning, to the issue of therapeutic cloning, reminiscent of utilitarian calculations of maximized outcomes (Beauchamp, 1982; DeMarco, 1996). The final quote, provided by participant 23 in response to the Huntington's disease gene therapy scenario, displayed a series of rationalistic concerns, including consideration of the evolutionary implications of gene therapy, the financial cost of gene therapy, and the potential for further stratification of social classes as a result of gene therapy.

Emotive Informal Reasoning

Emotive informal reasoning can be described by a care perspective in which empathy and concern for the well-being of others guided decisions or courses of action. This mode of care-based reasoning was evident throughout the investigation of socioscientific decision making.

Students frequently articulated ideas and positions that reflected concern for the individuals that would potentially be impacted by their decisions. The following quotes provide examples of this pattern of informal reasoning:

- 4F(RC): I can relate to this personally because my cousin who is very close to me—she and her husband have been trying to have a child for a very long time and they have been taking infertility drugs. For like 5 years they have not been able to have kids. I see the way that it affects them because they really want to have kids and I think that if that was an option and it worked, then yeah, I think they should be able to do that.
- 8F(HD): Yes because it takes away—it looks like it would take away from someone having to suffer for 20 years, and then you would not have to die so early either. So, I think it is a good idea. It could increase your lifespan. I think that if you can correct it or come up with a cure then you should.
  8S(HD): [I thought about] the fact that I do not like to see people suffer and if there's something like this that can eliminate it, then why not?
- 17F(HD): I think it would be fine if it is going to help the baby . . . If the disease is going to be detrimental to the human, then why not fix it at an early age if you can . . . If we have the ability to keep someone from suffering in the future, then why not? As far as someone thinking it is against the course of nature, I just think that is not a good excuse to let someone suffer.

These specific excerpts are representative of many others that revealed a tendency for students to consider genetic engineering issues with an empathetic or relational perspective. Responding to the reproductive cloning scenario, participant 4 considered the plight and feelings of her cousin who was actually experiencing an aspect of the scenario to which she was responding. The Huntington's disease gene therapy scenario evoked empathy toward potential disease sufferers from both participants 8 and 17. In all three cases, and many others throughout the interview transcripts, the decision makers' concern for the suffering of others contributed significantly to their resolution of the socioscientific issues they faced.

Intuitive Informal Reasoning

Intuitive informal reasoning was based on an immediate reaction to the context of a particular scenario. Intuitive informal reasoning was the result of a ‘‘gut-level’’ reaction or feeling that could not necessarily be explained in rational terms. Based on this description, the phrase ‘‘intuitive reasoning’’ may sound oxymoronic; however, reasoning in this sense is used to indicate informal reasoning, which was previously operationalized as the process by which individuals make decisions regarding controversial issues, including socioscientific issues. Intuitive feelings may not be rational, but because they contribute to the resolution of socioscientific issues, they may be considered a type of informal reasoning. The following excerpts were taken from individuals displaying intuitive informal reasoning during the interviews:

- 9F(RC): I just do not think that is right. I do not really know why; it is just this feeling. I do not think it is a good idea.
  9S(RC): I do not know how to sum it up, but it just does not seem right. I do not have any specific reasons.
- 11F(DC): That just seems wrong. You cannot replace your child—you can't replace—you just can't . . . I don't know that is just too weird.
- 16F(RC): No! [Reproductive cloning should not be permitted.]

Int: Why not?
16F(RC): You are basically going to have like your wife growing up in front of you again. That is just wrong I think. It is basically like having another twin come after you. I do not think that is right…You don't even know if that person is real.
Int: What factors contributed to your decision?
16S(RC): Just that—it is not right. I guess it goes against my religion.

These statements and others that exhibited similar patterns suggested that at least some issues were resolved according to an individual's immediate reaction. Most intuitive responses were negative, as evidenced by the examples; however, in a few instances during the interviews, individuals seemed to base a decision on a positive response to an issue. In either case, the decision makers did not make empathetic responses or rationalistic calculations; rather, they experienced an immediate feeling that influenced how they resolved the issue.

An alternative interpretation of this category might be that, rather than signaling a unique reasoning pattern, these responses simply indicate an inability to express one of the other forms of reasoning. Participants might have just been "tongue-tied." We mention this alternative because it is certainly possible to arrive at this conclusion based on the limited amount of data that can be presented in a single article. However, based on our analysis of the full transcripts, including participant responses to questions asked in the second interviews specifically designed to clarify the meaning of comments provided during the first interviews, we assert that the most likely explanation of the evidence produced in this study is that of an intuitive reasoning pattern. In our best judgment as researchers, the comments classified in this category represent more than simply being unable to articulate an idea. Some participants based their decisions on gut-level, intuitive reactions, a phenomenon that has been observed in other controversial decision making contexts (Haidt, 2001).

Integrated Patterns of Informal Reasoning

The three patterns of informal reasoning (i.e., rationalistic, emotive, and intuitive) did not always operate independently. Individuals frequently displayed multiple reasoning patterns in the resolution of single scenarios. For instance, some students exhibited empathy toward a character in a scenario and raised rationalistic concerns regarding the same scenario. Given the three primary forms of informal reasoning, there existed the possibility for three paired combinations: rationalistic and emotive reasoning; emotive and intuitive reasoning; and rationalistic and intuitive reasoning. The transcripts provided evidence in support of all of these combinations. In fact, each combination was displayed in two separate ways: the reasoning patterns could have been coordinated or conflicting. In addition to the paired combinations, some students employed all three reasoning patterns in response to a single scenario. These interactions are visually displayed and labeled using the Venn diagram presented earlier (Figure 1), and explanations of each possible combination are presented in Table 1. It should be noted that each region designating the integration of informal reasoning modes (labeled A, B, C, and D) represents both coordinated integration and conflicting integration. Table 2 exhibits a series of excerpts that provide examples for each overlapping pattern.

Intuitive reasoning always preceded the other types of reasoning. This pattern is not evident in all of the quotations in Table 2, but only because these excerpts represent small portions of the full interviews. Analysis of the complete transcripts revealed that, if an individual displayed intuitive reasoning along with emotive or rationalistic reasoning, then the intuitive thoughts always occurred before emotive or rationalistic reasoning. The pattern of intuition preceding empathy and

Table 1
Integrated modes of informal reasoning

Code and Interaction	Interpretation
A	
Coordinated	Rationalistic and emotive reasoning patterns are complementary.
Conflicting	Rationalistic reasoning conflicts with emotive reasoning.
B	
Coordinated	Emotive and intuitive reasoning patterns are complementary.
Conflicting	Emotive reasoning conflicts with intuitive reasoning.
C	
Coordinated	Intuitive and rationalistic reasoning patterns are complementary.
Conflicting	Intuitive reasoning conflicts with rationalistic reasoning.
D	
Coordinated	Rationalistic, emotive, and intuitive reasoning are integrated.
Conflicting	Any of the pairwise combinations described above are possible.

Note: Code corresponds to the symbols used in Figure 2.

reason was conceptually predictable. Intuitive reasoning was defined as an immediate affective reaction to a scenario, so the fact that individuals seemed first influenced by these feelings was not surprising. Individuals who exhibited intuitive reasoning frequently used emotive and rationalistic reasoning to subsequently support their initial reaction. (This pattern is shown in Table 2, B- and C-coordinated quotations.) However, some individuals experienced an immediate reaction to a particular decision, but subsequently considered contradictory emotive or rationalistic concerns (evidenced in Table 2, B- and C-conflicting quotations).

No consistent patterns emerged in terms of how rationalistic and emotive reasoning were integrated. Participants varied on an individual basis in terms of which types of reasoning patterns exerted more influence on their ultimate decisions. The strength of either emotion or reason depended on the participants' interpretations of the scenarios to which they were responding. However, the manner in which intuitive reasoning was integrated with the other modes of reasoning did reveal a trend. Although individuals employed intuitive reasoning less frequently than the other patterns of reasoning, it usually was more influential than other thought patterns. If a participant expressed an immediate reaction to an issue, then he or she almost always used this reaction as a guide for his or her ultimate position, regardless of other concerns.

The Significance of Context

The frequencies with which the different modes of reasoning were applied were variable across scenarios, indicating that the context of an issue significantly influenced how individuals responded to that issue. Table 3 displays the number of participants who employed each different reasoning pattern across the six scenarios they discussed. An individual's response to a single scenario could have been classified with multiple reasoning patterns. Because the frequency counts did not represent independent measures, inferential statistics, such as a chi-square analysis, were not appropriate. Therefore, these data were presented as a description of trends evidenced in this particular sample.

A majority of participants consistently exhibited patterns of rationalistic informal reasoning in every scenario, suggesting that, of the three reasoning patterns identified, rationalism was the least context dependent. Despite the specifics of each scenario, a minimum of 73% of the sample made comments during the discussion of each scenario consistent with rationalistic reasoning.

Table 2
Student responses that reveal integrated patterns of informal reasoning (Bold text represents evidence of rationalistic reasoning; underlined text represents evidence of emotive reasoning; and italicized text represents evidence of intuitive reasoning)

Code	Quotation
A	
Coordinated	• 11F(DC): I would say I agree with this because look at this couple who has been through all this and has tried and tried. **And it is not your body; it is theirs. It is not going to affect your kid or you having kids, but it is their responsibility. I think it is their choice.** • 17F(TC): I think in this case, yes. It kind of goes back to what I said with Huntington's disease—If you can try to fix something that is detrimental, that is life-threatening, then why not do it? **I think this is the reason that people would not want this to happen because they think it is a baby. But I believe in abortion and I do not think that before a baby is born it is an actual baby. That is why I would not see the embryo as a live baby. That is why I would agree with it in this case**. Because it can help someone. Certainly, if someone in my family was suffering from kidney disease, I would want it.
Conflicting	• 6F(IN): I think kids already have a hard time going to school and if you have an intelligence deficiency, it would be even worse. You just will not lead a normal life. You would always have to be taken care of instead of taking care of yourself. So if we used this, it would give the person a better life . . . [**But] I don't know. I think that not everyone is meant to be intelligent. There is a reason why some of us are intelligent and others are not intelligent.** • 21F(TC): **Part of me thinks that life is life as soon as the egg is fertilized** . . . **We would be trying to differentiate it into a liver so part of me wants to say no, do not do this because life starts when it is fertilized**, but another part of me says that it is not worth letting someone die over this. This issue is not worth letting someone die . . . **That [sacrificing an embryo] is sort of against what I believe**, [but if there are] patients that are dying right now because they're not getting anything, then I would say yes.
B	
Coordinated	• 4F(HD): *Yeah, I think that would be OK.* Int: Why? 4F(HD): *I don't know. I've never been really that into science, but I find a lot of it interesting. I don't know. Even just like—I don't know how to explain the way I feel.* 4S(HD): I just keep relating to a show that I saw. The father killed himself and he had three sons and two of them had the disease and were put in a nursing home in their 40s and their mother ended up shooting them. It was very bad. She ended up killing them because they went on these uncontrollable rages and would be beat her and stuff. She put them in a nursing home, but they begged her to shoot them because they could not deal with it and she did. I can't imagine—it was her own kids. It was pretty horrible. I do not think that anyone should have to go through something like that. • 27F(RC): *This is a little strange. They are going to look exactly like the person because they're going to have the same DNA. That is a little strange—it just sounds a little weird. I do not know if I want to have an exact copy of me running around. That is startling—I don't know—it just seems strange.* 27S(RC): I think that adoption would be an option that might be a little bit better because the baby will not have a home anyways so putting it with people would be better than not having a home.
Conflicting	• 28F(DC): *I do not know about that one. I think cloning people in general is very sci-fi, very weird, very in-the-future. I do not know if I agree with that.* But I am not in her shoes either. That is a tough call. This woman just lost her husband and her baby and now she wants a clone of her deceased child . . . [I thought about the fact that] she starts the day with a new baby and a husband and now she is left alone with nothing.

Table 2
(Continued)

Code	Quotation
	• 24F(AC): *I do not really have a set reason why this should not be done but I just do not think that it should be done. It is not because it was not fit to survive; it just seems creepy . . .* I can see how you would want to do this because it did not have much time to live and then it could live through this cloned baby . . . I guess a mother who has lost a child would give anything to have her child back.
C	
Coordinated	• 7F(IN): No, I do not think genetics should be used for intelligence . . . **If you did genetic intelligence and everyone did genetic intelligence, then there would be no jobs. Everyone would be going for the same jobs like engineering and biology**. *That would just be—I do not think you should—just like I do not think you should pick the sex of a child. You should not be able to pick intelligence or eye color.* Int: What is it about those things that you find objectionable? 7F(IN): *You know, I just think that it is wrong. I think it is morally wrong. I think it is wrong for someone to be able to determine your intelligence*.
	• 16F(IN): *No! That has moral and ethical issues attached to it . . . No, this one is really weird. This would be really bad . . .* **A person's intelligence is what they learned by and how they learned. If they do not have education, then of course they are not going to be intelligent, but everyone who has education usually has pretty good intelligence. And they can make their own decisions. If you just change the gene, then everyone would be thinking the same way.**
Conflicting	• 30R(RC): *I would be initially against it. I do not think it is natural . . . I cannot really pinpoint [a reason] because I am having trouble with this. It does not seem right—that was my initial reaction. It just does not seem right. I do not know how to expound on that . . .* **This seems to be getting closer to maybe you can make it a personal choice** . . . **I would not want to do it but other people can. I would lean toward making it a personal choice. It is not my right to tell people how they should live.**
	• 10F(DC): *Personally, I think that is a little freaky—the fact that you want to have the same baby from your dead husband—you want to make a baby from your dead husband? I think it is a little weird! I just don't know . . .* **If other people want to do it, then I think they should do it** . . . **People have a right to do it. Personally, I would not, but they should have a right to do it.**
D	
	• 13F(TC): *What kind of woman would be willing to do that? What kind of woman would be willing to*—**I guess they are just giving themselves up for a month. And they just take the stem cells out and that is it.** *There's something about that the does not strike me as morally right. . .* I feel bad for people who need organs and organ transplants and maybe it would help a lot but at the same time it is not natural at all. **There are organ donors out there naturally and they are going to die and something is going to happen so that they can give up their organs. I know there's a shortage—it is obvious that there is a shortage of organs donors in the world, but that is the way it is, that is the way it goes.** Something like this, I would not agree with.
	• 22F(AC): I know it sounds horrible, but I disagree because it is like you're telling this mother, this woman—I do not know what the love of a mother is like but I assume it is pretty strong—you are telling her that she cannot have her baby . . . We are telling her that she cannot have [her baby] and we are telling her that she cannot have anything left of her husband because she could not have another baby with him . . . *[But] I would say that it is more of a moral issue . . . Cloning—cloning a whole human and cloning whole organisms is still—maybe it is just the fact that our minds are not used to it maybe it is just the fact that this is new—maybe in time people will accept it, but me personally I cannot support it, not right now . . .* **Cloning also causes problems in terms of diversity. The diversity of genetic material has brought us to where we are. Whether you believe in evolution or not, even today there are isolated cases of survival of the fittest. It is because of diversity in genetic material and that's what keeps making advances in humanity and nature.**

Table 3
Informal reasoning patterns displayed in each scenario

Mode of Informal Reasoning	Scenarios						Totals
	HD	NS	IN	RC	DC	TC	
Rationalistic	22 (73%)	29 (97%)	30 (100%)	26 (87%)	23 (77%)	27 (90%)	158 (88%)
Emotive	24 (80%)	4 (13%)	3 (10%)	18 (60%)	15 (50%)	21 (70%)	85 (47%)
Intuitive	1 (3%)	1 (3%)	9 (30%)	15 (50%)	15 (50%)	4 (13%)	45 (25%)

HD, Huntington's disease gene therapy; NS, nearsightedness gene therapy; IN, intelligence gene therapy; RC, reproductive cloning; DC, deceased child cloning; TC, therapeutic cloning. The percentages, listed in parentheses, represent the proportion of individuals who displayed a particular mode of informal reasoning.

The data suggested greater context dependence for emotive and intuitive informal reasoning. The incidence of emotive reasoning ranged from 80% in the Huntington's disease gene therapy scenario to 10% in the gene therapy for intelligence scenario. Whereas emotive reasoning fluctuated greatly among the gene therapy scenarios, the frequency of its use remained relatively high across all of the cloning scenarios. These patterns suggest that emotive reasoning varied by issue (i.e., cloning in general was more likely to elicit emotive reasoning than gene therapy) as well as the specific contexts presented by individual scenarios (i.e., one gene therapy scenario was more likely to elicit emotive reasoning than the others).

Although intuitive reasoning was displayed in only 25% of the total number of decisions made, the role of intuitive reasoning was significant in some individual scenarios. Almost one third of the sample, in response to the intelligence gene therapy scenario, and one half of the sample, in response to the reproductive and deceased child cloning scenarios, relied on intuitive reasoning. Even in the scenarios with high incidences of intuitive reasoning, the other reasoning patterns were more frequent; however, the fact that intuitive reactions typically determined an individual's ultimate decision (as described in the previous section) suggests that intuitive reasoning was a significant factor for the resolution of some socioscientific scenarios.

The Role of Morality and Ethics

Consistent with previous studies of socioscientific decision making, the participants in this investigation tended to perceive moral and ethical implications of the issues presented to them. The following interview excerpts exemplify comments offered in response to a question in the second interview pertaining specifically to the morality of genetic engineering:

- 11S(RC): Any controversial subject—people will always say that it is an ethical or moral or against God or against nature. So yes, I took that into consideration. I'm not saying that these are all my views, but I know how the world is. For other ones [scenarios]—like the accident [DC] one—I just think that would hurt everyone in the long run.
- 19S(HD): [Gene therapy is a moral issue] because it would have to be done before birth and then you are subjecting a helpless life to something and you are making decisions for it—so, yes [gene therapy does involve morality]. You have a responsibility to another life.
- 25S(HD): Any kind of manipulation that we do to the genetic level is going to involve some kind of moral or ethical implications because it is messing with something fundamental to the way that we are.

Despite the fact that most participants (28 of 30) explicitly acknowledged the morality of genetic engineering issues, their perceptions of morality did not necessarily determine their decision making. The interview results suggested that the participants did concern themselves with moral aspects of the socioscientific issues they faced, but those moral considerations were not isolated or distinct from other aspects of the participants' informal reasoning. The participants integrated moral concerns with all other factors that contributed to their negotiation of the issues, including social factors and personal experiences. The participants seemed to recognize moral implications of the scenarios they confronted, but these considerations were not partitioned as if they occupied a unique domain, as suggested by some moral psychology researchers (Bersoff, 1999; Saltzstein, 1994; Turiel & Smetana, 1984). Informal reasoning seemed to meander between moral and nonmoral factors and, in the cases of many participants, it became impossible to distinguish between the two.

Discussion

Our findings support previous work (Bell & Lederman, 2003; Fleming, 1986; Pedretti, 1999; Sadler & Zeidler, 2004) that has highlighted the significance of morality for socioscientific decision making. However, this analysis suggests that attempts to isolate morality, and by extension personal or social factors, as a guiding factor in the determination of positions regarding socioscientific issues are misguided. Decision making influences, including morality, personal experiences, emotive factors, and social considerations, are subsumed in more complex patterns of informal reasoning. In response to gene therapy and cloning dilemmas, the participants in this study engaged in three distinct informal reasoning patterns: rationalistic; emotive; and intuitive. A significant trend to emerge from the data was the extent to which these different modes of reasoning were integrated into an individual's overall informal reasoning process. All participants exhibited at least one instance in which they relied on more than one pattern of informal reasoning to resolve an issue. Sometimes one pattern of reasoning supported another and, in other cases, two patterns exerted divergent influences. This pattern lends support to earlier conclusions (Pedretti, 1999; Yang & Anderson, 2003) regarding students' perceptions of socioscientific issue complexity. The display of multiple reasoning patterns was due at least in part to the recognition of the various perspectives that can influence positions taken in response to socioscientific scenarios.

The evidence produced suggests that the informal reasoning patterns invoked are related to the context of the socioscientific scenarios. Even though all of the scenarios involved genetic engineering, the incidence of emotive and intuitive reasoning seemed to vary among scenarios. (Rationalistic reasoning remained relatively high for all scenarios.) Although feminist approaches to morality (Belenky, Clinchy, Goldberger, & Tarule, 1986; Gilligan, 1982; Tronto, 1987) have adopted a variety of theoretical positions on the nature of morality, they have consistently highlighted the important role played by context. They have revealed how the context of issues or scenarios is integral to decision makers' negotiation of controversial issues. The present study corroborates the significance of context, especially for socioscientific decision making, a result further supported by Korpan et al. (1997) and Zeidler and Schafer (1984).

Educational Implications

A few recommendations for science education can be made based on these findings. First, if the aim of science education involves, in part, the promotion of character and democratic citizenry, which involves moral decision making (Driver, Newton, & Osborne, 2000; Kolstø, 2001; Zeidler, 1984), then socioscientific issues are an appropriate component of the curriculum because students do, in fact, perceive moral and social aspects of these issues. This study empirically demonstrates the significance of morality embedded in the informal reasoning processes of individual decision makers. It stands to reason that continued exposure to socioscientific decision-making opportunities will provide students chances to explicitly explore their own principles, emotions, and intuitions pertinent to science and its social applications. This can only enhance their roles as citizen participants in democratic societies largely influenced by science and technology.

Second, if educators want to encourage a particular mode of informal reasoning, they can select certain socioscientific issues based on context. For instance, the participants in this sample displayed emotive informal reasoning in the case of gene therapy for Huntington's disease far more frequently than they did in the case of gene therapy for near-sightedness. This does not indicate that every sample of students will display the same pattern, but based on experiences with his or her students the teacher may be able to frame socioscientific issues in a manner that encourages different modes of informal reasoning.

Finally, if socioscientific issues, particularly genetic engineering issues, are incorporated in science curricula and classrooms, then designers and educators need to make room for the expression of affect. Rationalistic thinking patterns typify what is generally expected in science classrooms, and educators frequently strive to ensure the development of rationalistic thinking skills (Tweney, 1991). However, the results of this study suggest that rationalistic informal reasoning is only one of three ways that students might relate to socioscientific issues. Students may adopt relational perspectives based on empathy and care; in addition, they might be most influenced by their immediate, intuitive reactions. For students to be personally engaged in socioscientific issues presented in the classroom, they need an opportunity to express their personal ideas about the issues or at least need an environment in which their patterns of thought are valued. One of the rationales offered to support the development and implementation of socioscientific curricula is the tendency for this material to truly engage students (Cajas, 1999). If this is a goal, then educators must be prepared to consider and respect the manners in which students negotiate these issues, even when that includes patterns of reasoning not typically associated with science. If issues are presented only from a rationalistic perspective, which has been a hallmark of science education (Pool, 1991; Tweney, 1991), then many students are being excluded. The intuitive reactions, emotions, and reason-based concerns of students should be valued in the classroom. This recommendation is not meant to imply that students should not be challenged to consider the basis of their intuitive, emotive, and rationalistic reasoning patterns; in fact, they should. Educators can encourage their students to explore their own informal reasoning without prescribing a particular mode of reasoning by setting up a classroom environment in which only one type of informal reasoning is valued.

This suggestion introduces an interesting paradox for practitioners: How should we encourage natural patterns of affective expression in the context of SSI while promoting the primacy of evidence, which is central to the epistemology of science (McComas et al., 2000)? It is not difficult to imagine this challenge arising in a biology class that addresses cloning and evolution. By encouraging emotional responses to cloning scenarios in the context of a science classroom, do we implicitly suggest that other science topics, such as evolution, are also subject to emotion? We actually see this potential conundrum as an opportunity as opposed to an obstacle. It presents an opportunity to explore the nature of science, particularly the social aspects of science, the status of evidence, and the role of values in science. An important lesson that might emerge from the example just mentioned is that socioscientific decision making is a fundamentally different task than evaluating the merits of a scientific theory. A scientifically literate individual should have aptitudes in both, but the former situation involves normative judgments that may require emotive considerations and personal values, whereas the latter situation should entail evidentiary assessments. By explicitly attending to the distinct influences of values and evidence, SSI curriculum can actually facilitate student conceptualizations of scientific data, inferences, and theory generation.

Implications for Research

To develop a more robust understanding of how individuals of all ages negotiate socioscientific issues, and if informal reasoning regarding socioscientific issues demonstrates developmental trends, future work designed to explore the reasoning patterns of other target populations is necessary. Given the importance of socioscientific curricula for middle and high school classrooms (Chiappetta & Koballa, 2002; Trowbridge, Bybee, & Powell, 2000), studies with middle and high school student samples would be useful. Given the contextual significance of individual scenarios in the elicitation of multiple reasoning patterns, the exploration of reasoning in response to other socioscientific issues is also necessary. Although the scenarios used in this study all stemmed from a common content area (i.e., genetic engineering), the context of individual scenarios had important effects on the patterns of participant responses. To enhance the transferability of the findings reported herein, similar analyses must be completed with issues other than gene therapy and cloning. Scenarios that stem from content areas other than biology, such as nuclear power, global warming, and the search for extraterrestrial life, would be particularly useful in establishing a more generalized model of socioscientific decision making.

Although the three forms of informal reasoning (i.e., rationalistic, emotive, and intuitive) were usually integrated, the presence of intuitive reasoning was distinct. When it was expressed, intuitive reasoning always preceded other reasoning patterns and was frequently the primary determinant of the decisionmaker's ultimate decision. Given the unique status of intuitive informal reasoning, future studies should be undertaken to address whether intuitive reasoning possesses distinctive practical implications. For instance, the manner in which individuals handle evidence that conflicts with their intuitive reactions as well as the extent to which students are personally engaged by the issues that elicit these strong reactions would be valuable foci for future studies.

As a final call for new directions in the field, we believe that science educators should use the findings presented in this study as well as other theoretically motivated investigations (i.e., Bell & Lederman, 2003; Fleming, 1986; Korpan et al., 1997; Sadler & Zeidler, in press) to develop research-based programs for infusing socioscientific issues into science classrooms. This research supports the idea that socioscientific issues can be classroom topics that serve to engage students, exercise students' value commitments, promote conceptual learning of related content, support scientific argumentation, and encourage the development of informed epistemologies. How to best achieve these ends presents an important research agenda, an agenda with difficult methodological issues and complicated and uncontrollable variables. This research may be difficult to conduct and produce "messy" results, but it remains necessary to achieve a vision of scientific literacy that actually prepares students to deal with the complexities of modern, scientific societies.

Appendix A: Interview Reading Prompts

Gene Therapy Description

Germ-line gene therapy is a potential genetic technology. (It has not yet been used in humans.) This type of gene therapy would involve altering a gene in an individual's sex cells (egg or sperm cells) or in a newly conceived embryo (just after fertilization). The intent of gene therapy would be to remove an undesirable gene and replace it with a preferred gene. The sex cell or embryo, resulting from gene therapy, would possess the "new" gene and would be missing the "old" gene.

Huntington's Disease Gene Therapy Prompt

Huntington's disease (HD) is a neurological disorder caused by a single gene. Its symptoms usually start between the ages of 35 and 45. The first symptoms include uncontrollable body spasms and cognitive impairment. As the disease progresses, patients become physically incapacitated, suffer from emotional instability, and eventually lose mental faculties. HD usually runs its course over a period of 15–20 years and always results in death. No conventional treatments are known to work against HD.

Because Huntington's disease is controlled by one gene, it could be a candidate for gene therapy. Should gene therapy be used to eliminate HD from sex cells (egg cells or sperm cells) that will be used to create new human offspring?

Near-sightedness Gene Therapy Prompt

Near-sightedness is a condition that affects millions of people worldwide. Near-sightedness, also known as myopia, manifests in blurred distance vision. Interventions such as eyeglasses, contacts, and corrective surgery are frequently used to treat this condition.

If science found a single gene that produced near-sightedness, should gene therapy be used to eliminate that gene from sex cells (egg cells or sperm cells) that will be used to create human offspring?

Intelligence Gene Therapy Prompt

We know that a person's intelligence is controlled by a variety of factors including both environmental and genetic influences. It is likely that several genes contribute to a person's intelligence. No single factor, whether genetic or environmental, could completely determine an individual's intelligence; however, it is conceivable that scientists could find a single gene that at least contributes to an individual's intelligence.

If science were able to isolate a gene that significantly contributed to a person's intelligence, should that gene be used for gene therapy to increase the intelligence of potential offspring?

Cloning Description

The process of cloning is designed to produce an organism genetically identical to another organism. In the normal process of mammalian reproduction, genetic material from an egg cell and a sperm cell combine during fertilization to produce a new genetic combination. The new genetic makeup of the offspring is distinct from both parents. The fertilized egg cell will eventually develop into a new offspring.

In cloning, the genetic material of an unfertilized egg cell is removed, and a complete set of genetic material (from a donor) is inserted into the egg cell. The donor genetic material can be relatively easily obtained from most body cells (e.g., skin cells). The egg cell that carries the donor's genetic material can be stimulated to grow as if it were a fertilized egg. The cloned offspring would be genetically identical to the donor organism.

Reproductive Cloning Prompt

Many otherwise healthy couples are unable to bear children. Modern reproductive technologies like fertility drugs and in vitro fertilization have enabled some of these individuals to have their own children. However, some couples remain infertile and unable to have a baby. For these individuals, cloning could be used as another reproductive technology. In this case, one of the parents would serve as the genetic donor. The donor's genetic material would be inserted into an egg cell, and then the embryo (the egg carrying a complete set of the donor's genetic material) would be implanted into the woman. The embryo would develop into a fetus and eventually be born as a baby.

Should individuals who want to carry and have their own children be able to choose cloning as a reproductive option?

Deceased Child Cloning Prompt

A couple and their newborn child (their only child) are involved in a terrible automobile accident. The father dies at the scene of the accident, and the baby is severely injured. The mother sustains only minor cuts and bruises. At the hospital, doctors inform the mother that her baby will undoubtedly die within a matter of days.

The woman wants to raise a child that is the product of her now deceased husband and herself. She would like to take cell samples from her dying child so that she can carry and give birth to a genetic clone of the child. Should this woman be able to produce a clone of her dying baby?

Therapeutic Cloning Prompt

Thus far, you have read about and discussed reproductive cloning. Although the technology and initial procedures involved in therapeutic and reproductive cloning are similar, the end-products and applications are different. In therapeutic cloning, a cloned embryo is created and stimulated so that it begins growing. (Just like reproductive cloning, this involves inserting the genetic material of a donor into an egg cell so that the resulting embryo is genetically identical to the donor.) The embryo would continue to develop until it has formed stem cells. (This ordinarily occurs within 3 weeks of the time the embryo starts growing.) At this point, the stem cells would be removed from the embryo. Stem cells are unique because they can be stimulated to develop into many different types of body tissues. For example, they can produce kidney tissue that could be transplanted into individuals with kidney disease or nerve cells that could be used for individuals suffering from spinal cord injuries or Parkinson's disease.

Two major problems are associated with organ transplantation: a lack of available organs, and immunological rejection. There are far more patients waiting for transplants than there are donated organs. In addition, the immune systems of patients who actually receive transplants often reject the transplanted organ because the body recognizes it as a foreign substance. Organs and tissues produced by means of therapeutic cloning would solve both of these problems. Patients awaiting transplants could donate their own genetic material for the production of the cloned embryo. Because the resulting tissue or organ would carry the same genetic material as the patient, the immune system would not reject it. Should therapeutic cloning be used to develop tissues for patients who need transplants such as individuals suffering from fatal kidney disease?

Appendix B: First Interview Questions

The questions listed were posed after each participant read the Huntington's disease gene therapy prompt. Similar questions (modified according to the content of each scenario) were asked after participants read each scenario prompt:

1. Should gene therapy be used to eliminate HD from sex cells (egg cells or sperm cells) that will be used to create new human offspring? Why or why not?
2. How would you convince a friend or acquaintance of your position?
3. (*If necessary*) Is there anything else you might say to prove your point?
4. Can you think of an argument that could be made against the position that you have just described? How could someone support that argument?
5. If someone confronted you with that argument, what could you say in response? How would you defend your position against that argument?
6. (*If necessary*) Is there anything else you might say to prove that you are right?

Appendix C: Second Interview Questions

The questions listed refer to the Huntington's disease scenario. Similar questions (modified according to content) were asked regarding the deceased child cloning scenario:

1. What factors were influential in determining your position regarding the Huntington's disease issue?
2. Did you immediately feel that gene therapy was the right/wrong course of action in this context? Did you know your position on the issue before you had to consciously reflect on the issue?
3. In arriving at you decision, did you consider the perspective or feelings of anyone involved in the scenario? (a) Did you consider the position or feelings of a parent faced with giving birth to a child that has HD? If so, how did this affect your decision making? (b) Did you consider the feelings of a potential child carrying the HD gene? If so, how did this affect your decision making?
4. Did you try to put yourself in the place of either a potential parent or child? If so, how did this affect your decision making?
5. Do you think that gene therapy as described in this case is subject to any kind of moral rules or principles? If so, how did this affect your decision making?
6. Did you consider the responsibility of parents? If so, what are the responsibilities of the parents in this scenario?
7. Did you consider whether or not a parent has the right to alter the child's genes? If so, how did this affect your decision making?
8. Did you consider the rights of the future child? If so, how did this affect your decision making?
9. Did you think about the roles and responsibilities of the doctors who would perform the gene therapy? If so, how did this affect your decision making?
10. Did you consider the child's future with and without gene therapy? What aspects of the child's future did you think about, and how did it shape your position?
11. Did you consider possible side effects for either the mother or the potential child. If so, how did this affect your decision making?
12. Were you concerned with any technological issues associated with gene therapy? If so, what issues did you think about?
13. Did you think about who would have access to gene therapy? If so, how did this affect your decision making?

14. Is there anything else that I might know about your thinking process or decision making as you considered this gene therapy issue?

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